The Influence of Cement Spacer Thickness on Retentive Strength of Monolithic Zirconia Crowns Cemented with Different Luting Agents (A Comparative *in-vitro* Study)

Reyam H. Ali[1], Mohammed Kassim[2]

[1]B.D.S, Ministry of Health; Post Graduate / Department of Conservative Dentistry, College of Dentistry, Mustansiriyah University, Baghdad, Iraq, [2]B.D.S M.Sc. Ph.D, Assist. Prof./ Department of Conservative Dentistry, College of Dentistry, Mustansiriyah University, Baghdad, Iraq

Abstract

Aims of Study: to evaluate and compare the retentive strength and the failure-modes of monolithic zirconia crowns with different cement spacer thickness, cemented with two different types of luting agents.

Materials and Methods: Forty sound maxillary first premolar teeth were divided into two main groups (n=20): Group A: cement spacer thickness of 80µm; Group B: cement spacer thickness of 120µm. The groups were further subdivided into two subgroups (n=10): (A1, B1) cemented with Panavia F2.0 resin-cement; (A2, B2) cemented with Riva luting plus RMGIC. All the teeth were prepared to receive monolithic zirconia crowns with the following features: (6º convergence angle, 0.8mm deep chamfer finishing line, 4mm axial wall height with planar occlusal reduction). Afterwards, the teeth were scanned and the crowns were fabricated and cemented. Zirconia crowns were pulled-out along its path of insertion using universal testing machine. Failure stresses were calculated in MPa. Failure-modes was assessed using magnifying-lens (2.5X).

Results: The highest mean retentive values (in Mpa) was recorded by subgroup B1 (8.651); followed by subgroup B2 (7.765); subgroup A1 (7.309) and subgroup A2 (6.875). Independent t-test showed a statistically significant difference between A1 and B1 subgroups. Concerning the failure-mode, the majority of samples revealed adhesive failure between teeth and cement.

Conclusion: All the tested crowns have mean retentive values within the clinically acceptable limit, increasing cement space resulted in a significant increase in the retention when Panavia F2.0 used as a luting agent, while, it has no significant effect on the retention when RIVA luting plus was used.

Keywords: *cement space, monolithic zirconia, resin-cement, retentive strength, RMGIC.*

Introduction

Over the past few years, there has been a remarkable shift towards high-strength, all-ceramic restorations; In-particular those fabricated from zirconium-oxide (ZrO^2) ceramics, because of their esthetic, biocompatibility and mechanical properties [1]. A common cause of failure of crowns and bridges was reported as a loss of retention [2]. Retention form could be defined as the quality of the preparation that prevents the restoration from being dislodged by such forces parallel to its insertion pathway. Retention is dependent on several factors such as form of prepared teeth, roughness of the intaglio surface of the crown restorations, type of cement and its film thickness [3]. Furthermore, fitness of crown restorations plays a substantial role in their retention [4]. Previously, researchers theorized that better retention could be attained with the frictional fit between the intaglio surface of the restoration and the tooth preparation [5]. However,

Corresponding Author:
Reyam H. Ali
retajcom@uomustansiriyah.edu.iq,
riyamhashim8@gmail.com

this theory has been rejected because a perfect fit could not be attained during the cementation, due to the lack of space for the cement [6]. Many researchers have agreed that final fitness of the restoration after cementation would be improved by providing cement spacing during crown fabrication. Consequently, the retention of the cemented crown could also be improved [7]. Cement spacer permits increased space for the luting agent thus reducing stress formed during cementation, resulting in improved fitness and retention of the restoration [8]. Conversely, if the cement space was exceedingly wide, the seated crown will be loose on the preparation; the probability of crown loosening during function would considerably increase, compromising its longevity [3].

Definitive cementation represents an essential step through the restorative procedure. The precise selection of luting agent and standardized application of cementation protocol are crucial for proper retention and sufficient marginal sealing of the restoration in time [9].

The objectives of this study were to evaluate and compare the influence of difference in cement spacer thickness on the retentive strength of monolithic zirconia crowns cemented with two different types of luting agents (adhesive resin-cement and resin-modified glass-ionomer cement) and to evaluate the failure-modes of tested crowns.

Materials and Methods

Forty sound human maxillary first premolar teeth extracted for orthodontic purpose from patients with the age of 18-23 years had been used in this study, only teeth with two-separated roots were selected to withstand removal from the imbedding-resin during testing, the teeth were cleaned and then disinfected in 1% thymol solution for 48 hours to avoid fungal and bacterial growth. U-shaped notches were made on each root to act as a mechanical mean for retention [10], each tooth was embedded in specially-fabricated cylindrical rubber-mold containing cold-cure acrylic (Veracril, New Stetic, Colombia) parallel to the long axis to within 2mm apical to the CEJ to simulate the biologic width with the aid of dental surveyor (Paraline, Dentaurum, Germany).

Teeth were randomly divided into two groups (n=20), according to the cement spacer thickness used as: Group A (80µm) and Group B (120µm). They were further subdivided into two subgroups (n=10) according to the type of luting agents: subgroup (A1, B1) cemented with adhesive resin-cement (Panavia F2.0, Kuraray, Japan) and subgroup (A2, B2) cemented with resin-modified glass-ionomer luting cement (RIVA luting plus, SDI, Australia).

Teeth samples were prepared to receive monolithic zirconia crowns (Katana zirconia ML A light, Kuraray, Japan) according to the following criteria: 6-degree total convergence angle, a planar occlusal reduction, 0.8mm deep chamfer finishing line and 4mm axial height from the finishing line to the occlusal level buccally and palatally (Figure 1).

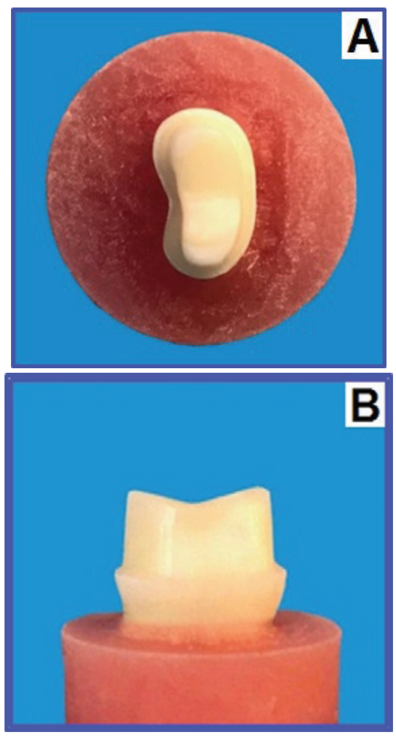

Figure (1): Finished prepared tooth

A: Occlusal view, B Lateral view.

Samples scanning was performed using powder-free digital scanner (in-Eos X5 in-lab scanner, Sirona, Germany). Measurement of the surface area for the scanned preparation was performed using AutoCAD architecture software. During designing procedure, the zirconia crowns were deliberately received four macro-retention bars to help removal of the crown after cementation [11], 5-axis milling machine (In-Lab MC X5 milling machine, Sirona, Germany) was used to produce the zirconia crowns.

After completion of sintering procedure, the intaglio surface of each crown was air-abraded with 50µm aluminum-oxide for 15 seconds using 4-bar pressure at 10mm distance and 45˚ angle (Pneumatic sandblasting unit, Renfert, Germany). Afterwards, the crowns were cleaned in an ultrasonic cleaner for 5 minutes to remove any residue of blasting agent.

For Panavia F2.0 resin-cement subgroups, two coats of zirconia primer (Z-PRIME Plus, Bisco, USA) were applied to the intaglio surface of the restoration and then lightly air-dried for 5 seconds according to manufacturer's instruction. Equal amounts of primer (ED primer II A and B, Kuraray, Japan) were mixed for 5 seconds and applied to the tooth surface, left for 30 seconds and lightly air-dried for 5 seconds. Equal amounts of the two pastes (one complete turn for each paste) were mixed for 20 seconds according to manufacturer's instruction, the cement was evenly distributed on the intaglio surface with a pen brush.

For resin-modified glass-ionomer cementation, 37% phosphoric acid gel (Super Etch, SDI, Australia) was applied to the prepared tooth for 5 seconds then rinsed with water and air-dried according to their manufacturer's instructions. Riva luting plus capsules were mixed for 10 seconds then the cement was injected into the crown.

The cementation procedure for all subgroups was performed using a modified dental surveyor under a constant load of 5-Kg for 5 minutes. The excess cement was removed with a microbrush followed by curing for 20 seconds per surface for resin-cement subgroups according to the manufacturer's instructions. Thereafter, the samples were stored in deionized water at room temperature for 7 days.

Before the tensile-test, each crown was embedded in a clear cold-cure acrylic-resin (Duracryl® Plus, Kerr, Crech) using a second cylindrical rubber-mold. A stainless-steel screw was incorporated at the top parallel to the long axis of the tooth with the aid of an adapted surveyor [9]. The upper mold was separated from the lower one by 3mm thick sheet of rubber.

After 24 hours, the entire apparatus was mounted in (computer-controlled universal testing machine, Laryee, China) and pulled along the path of insertion in a crosshead speed of 0.5mm/min until failure. The dislodgment force was recorded in (N), divided by the surface area of each preparation in (mm^2) to yield the retentive stress in (MPa).

After completion of the test, all samples were examined using a magnifying-lens (2.5X) to assess the failure-modes, according to the classification by Gundogdu and Aladag in 2018 [12] (Table 1).

Table 1: Modes of failure as described by Gundogdu and Aladag in 2018 [12].

Mode of failure	Nature
Type I	Cohesive failure in teeth.
Type II	Adhesive failure between teeth and cement.
Type III	Cohesive failure in the cement.
Type IV	Adhesive failure between the cement and zirconia surface.
Type V	Cohesive failure in ceramic.

Statistical analysis of data was performed using SPSS program (Statistical Package for Social Science, IBM Corp., USA).

Results

The descriptive statistics (means, ±SD, Min. and Max.) for each subgroup are presented in (Table 2).

Table 2: Descriptive statistics of retentive strength values of the different subgroups measured in MPa.

Groups	Subgroups	N	Mean	±S.D.	Min.	Max.
A	A_1	10	7.309	1.232	5.313	8.999
	A_2	10	6.875	1.445	4.891	8.706
B	B_1	10	8.651	1.458	5.698	10.597
	B_2	10	7.765	1.728	4.563	9.632

The highest mean retentive values in MPa was recorded by subgroup B1 (8.651); followed by subgroup B2 (7.765); subgroup A1 (7.309) and subgroup A2 (6.875) (Figure 2).

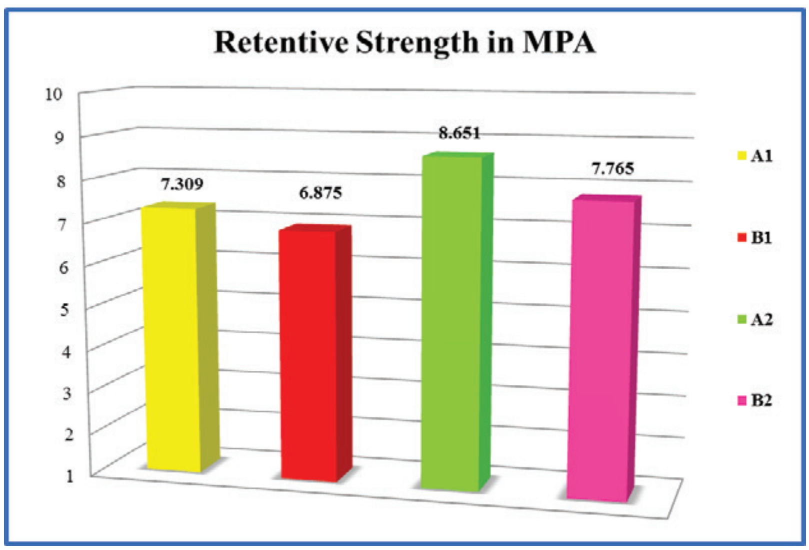

Figure 2: Bar-chart showing the mean retentive strength values for all subgroups in MPa.

Independent samples t-test was used to analyze the data at a level of significance ($P \leq .05$), the test disclosed a statistically significant difference between B1 and A1 subgroups while a statically non-significant difference between the other subgroups has been revealed by the test (Table 3).

Table 3: T-test for comparison of significance between subgroups.

Subgroup	t-test	Df	Sig.
A1&A2	.722	18	.480* [NS]
B1&B2	1.238	18	.232* [NS]
A1&B1	-2.223	18	.039* [S]
A2&B2	-1.249	18	.228* [NS]

*** The mean difference is significant at the 0.05 level.**

The results for characterization of failure-modes were generally adhesive in nature as illustrated in (Table 4).

Table (4): Mode of failure of the different subgroups.

Groups	Subgroups	Type I (%)	Type II (%)	Type III (%)	Type IV (%)	Total (%)
A	A1	2 (20%)	5 (50%)	1 (10%)	2 (20%)	10 (100%)
	A2	1 (10%)	3 (30%)	3 (30%)	3 (30%)	10 (100%)
B	B1	1 (10%)	8 (80%)	-	1 (10%)	10 (100%)
	B2	-	5 (50%)	1 (10%)	4 (40%)	10 (100%)

Discussion

Retention is considered as one of the essential elements which determine the long-term clinical-success of dental prosthesis. There is no single factor on which retention is entirely dependent. In-fact, retention involves a list of factors, all of which have to be taken into account during all stages starting from teeth preparation to the final cementation. Even if a single factor is accidentally neglected it can affect the retention of the crown restorations which further has a direct impact on the longevity of the restoration [13]. Monolithic zirconia crowns were selected for this study due to its superior physical properties that were pliable to the tensile pull-off test [11].

A total convergence angle of 6-degree was used in this study because it is considered as an ideal convergence angle that improves retention of crown restoration [13]. A planar occlusal reduction was performed because tooth should be prepared in accordance with a clinical simulation. Furthermore, greater surface area would be achieved (when compared to a flat occlusal reduction) thereby increasing its retention [14].

Because of high flexural strength, zirconia crowns can be cemented either non-adhesively using conventional cements or adhesively with the resin-cement. Therefore, RIVA luting plus RMGIC and Panavia F2.0 resin-cement were selected to represent two distinct groups of luting agents [15].

The results of this study have been showed that all the tested crowns have mean retentive values exceeding the clinically acceptable limit required to retain crown successfully according to Palacios et al.(2006) [10].

In this study we found that 120μm cement spacer thickness has significantly higher mean retentive values than 80μm cement spacer thickness for resin-cement subgroups. It might be explained as when ideal convergence angle would be used for the preparation (6-degree), the expression of the excess cement through this angle would be difficult, this will lead to filtration process causes the cement to separate into particles and liquid phase, allowing the passage of liquid phase while solid particles gathering occlusally which leads to the development of hydrostatic pressure under the crown that increases until it matches the seating force and causes further seating impossible [6,16]. Increasing space between the prepared tooth surface and the intaglio surface of the restoration, reducing stress areas formed during cementation, and thereby resulting in better fitness and retention of the definitive restoration [8]. This was in accordance with previous studies concerning the increase in the cement spacer thickness [17,18].

The results found in this study were inconsistent with that reported by Mehl et al.(2013) [19]. However, the different materials of the aforementioned study (titanium implant's abutments, cobalt-chromium crowns and different cementing systems) could be the reason for different results.

Another finding of this study concerning the type of luting agents used, when cement space thickness remains constant, the results showed non-significant difference in the mean retentive stresses for RIVA luting plus RMGIC when compared to resin-cement. This might be due to the chemical adhesion to dentin, improving the retention of RIVA luting plus RMGIC [20]. In addition, the use of phosphoric acid-etching enhanced the micromechanical retention of Riva luting plus RMGIC [21]. Furthermore, the grain particle size of Panavia F2.0 resin-cement (0.04-19µm) is relatively similar to the particle size of the resin-modified glass-ionomer luting cements (≈15µm) [22] which might lead to a relatively similar entanglement or hooking of filler particles to the dentin surface. However, in spite of the non-significant difference, a higher mean retentive values were recorded with Panavia F2.0 resin-cement subgroups than those of RIVA luting plus RMGIC subgroups. The findings of the present study are in agreement with the study by Ernst et al.(2005) and Palacios et al.(2006) [10,11].

Concerning the failure-modes, the majority of samples for all subgroups showed an adhesive failure (type II and type IV) (52.5% and 25%) respectively. This suggests that the mechanical interlock to air-abraded roughened zirconia surface was greater than mechanical interlock to the tooth [23] and might be also attributed to the application of Z-prime plus which enhances the bond strength of the resin-cement to zirconia crowns [24].

A number of studies had been performed to evaluate the influence of cement space on the retention of cemented crowns, their data produced inconsistent results. A clearly established experimental protocol is not evident from those studies rendering the comparison of results so difficult. Further research is needed to examine the effect of cement spacer thickness on crown retention, various crown material types, different surface treatments, different luting cements, long-term storage, thermocycling.

Conclusions

Within the limitations of this study, the following conclusions were drawn:

1- All the tested crowns have mean retentive values within the clinically acceptable limit required to retain crown successfully.

2- Increasing cement space thickness to 120µm would result in a significant increase in the retention values of zirconia crown restorations when Panavia F2.0 used as a luting agent. While it has no significant effect on the retention of crown restoration when RIVA luting plus was used as a luting agent.

3- The results for characterization of failure-modes were generally adhesive in nature.

Ethical Clearance: The Research Ethical Committee at scientific research by ethical approval of both MOH and MOHSER in Iraq

Conflict of Interest: None

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